Analog and Mixed Signal Damper System

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Two different damper topologies are discussed for the SNS ring. The first topology is a true analog system, while the other system is a mixed signal (analog and digital) system. The merits and problems with each system are discussed.

I. Introduction

It has been proposed to design and build a damper system for the SNS ring. It is desired to implement a bench test using the PSR ring at LANL, while our rings are similar in size, frequency, and will have similar instabilities. The proposal is to use existing BPM pickups from LANL as both pickup and kicker. Discussions about bandwidth and system performance show that a broadband damper system is desired and a realization of the technology using different techniques will be presented.

II. Analog System

A simple schematic of the analog damper system is shown in Fig. 1. A quick discussion of each component, from left to right follows. Starting from the left is the bpm electrode. The electrodes are terminated downstream with a resistor, and the upstream cables are then sent to a 180° hybrid. The sum port of the hybrid is terminated, and the difference signal is then sent to a high pass filter followed by a low pass filter, a delay line, a 100 pole filter, an equalizer, an

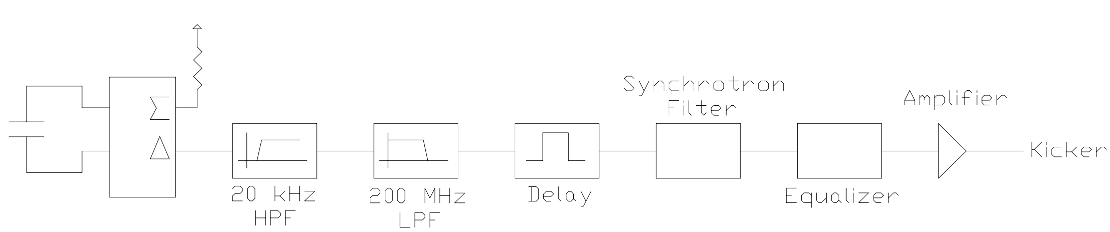

Figure 1. A schematic representation of an analog damper system. The elements of each component are described in detail.

amplifier, and finally the kicker (or another BPM electrode)

a. 180° hybrid

The hybrid is used to measure the difference in signal from one electrode to another. This is an essential operation to measure the difference in orbit for kicking the beam later on. A common problem that exists in hybrids is its CMR (common mode rejection). This is a metric which describes how well the hybrid performs in subtracting identical signals to its input ports. Typical performance of hybrids is -20 dB.

b) High Pass and Low Pass Filters

The amplifier at the end of the damper system will not have a DC response, and therefore it is required to filter out any DC component of the signal. Typical broadband amplifiers have a response to a few tens of kilohertz, and therefore a 3 dB point of 20 kHz is chosen.

It is also necessary to regulate the spectrum of the signal out to the amplifier so as to not excite additional modes of the beam. Since the pickup/kicker has a bandwidth to about 200 MHz, a 200 MHz low pass filter is chosen.

c) Delay Line

The delay line guarantees that the signals that get to the kicker are timed correctly. The delay line can be as simple as a long fiber and amplifier combination. The fiber would be temperature controlled so its electrical length remains constant. The fiber would have to be cut insitu so as the system length is optimized for the ring for installation.

d) Synchrotron Filter

The BPM will inherently pickup the beam revolution frequency and all of its harmonics. It is desired that the damper system not act upon these signals. The technical requirement for this system is, therefore, to place a pole at the revolution frequency and all of its harmonics. A simple circuit that has these properties is depicted in Fig. 2.

The delay section is equal to the time it takes for the beam to circulate around the ring, To. The signals transform to the output as

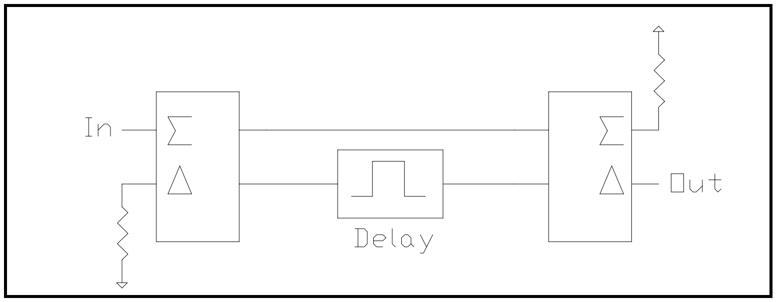

Figure 2. A simple schematic of the synchrotron filter. The delay section has a delay equal to the time it takes the beam to circulate exactly one time around the ring.

$A(\omega) \rightarrow \dfrac{A(\omega)}{2}\left(1 - e^{-i\omega T_o}\right)$. Examination of the output clearly shows a null for every harmonic of the revolution frequency.

Again, note that this topology requires the use of two 180° hybrids. The delay line is adjusted so that the nulls occur at exactly the harmonics of the revolution frequency. The delay line can be manufactured with fiber and use simple binary delay lines. This technique may also require that an additional equalizer be added to the delay line side, but is only known after fabrication.

e) Equalizer

This equalizer is designed and built after the entire system is designed, built, and installed. An equalizer may be important because the electrodes have nonuniform gain versus frequency, the cables have magnitude and phase dispersion, and typical amplifiers have phase dispersion. The goal in the design of the filter is to permit a signal to come into the system and have it come out only modified by its magnitude. This is to say that a signal that is picked up should be transferred to the kicker uniformly.

f) Amplifier

The amplifier section can be manufactured several different ways. If two amplifiers are chosen, they must be first measured to ensure that they have identical gain/phase characteristics.

If they are not, an additional equalizer will be required to be built. A 180° hybrid would then be driven, the outputs from the hybrid would then drive each amplifier and the outputs then driven to the kicker electrode.

If a single amplifier is chosen, a 180° hybrid would be placed downstream of the amplifier. A load would then be placed on the sum port, and the two outputs would then go to the kicker. Each output cable would then be required to be phase matched.

III. Mixed Signal Design

A mixed signal damper system can easily be designed which would outperform the analog system. It has special requirements, however, and great care needs to be taken to make this system perform to its peak levels. This design still may have many of the inherent issues in the analog system, and it will require more design work. A schematic of the Mixed Signal Design is depicted in Fig. 3.

A short overview of the mixed signal system follows: The signals come in identically from the electrodes. The signals need to be filtered before the digital signal processing can begin. The signals are first digitized and subtracted. The delay is then performed, followed by the synchrotron filter. The data is then sent to a DAC (digital to analog convertor), through an

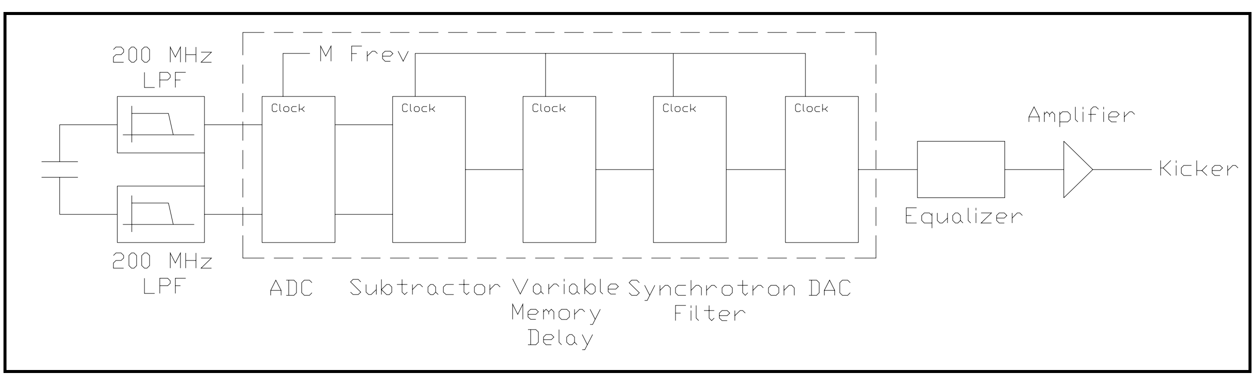

Figure 3. Mixed Signal schematic design of a damper system. The components in the dashed box would be performed digitally, while the rest of the system is analog.

equalizer, through an amplifier, and out to a kicker.

a) 200 MHz Low Pass Filters

The mixed signal damper system starts with low pass filters. These filters are necessary so that aliasing does not exist in the digital parts of the filters. These filters should be maximally flat so that their effect of dispersion on the system is minimal.

b) ADC

The ADC is clocked at a multiple M of the ring frequency. Since ADC chips exist fairly readily which have 10 bits and can perform out to 1 GSa/sec, the S/N of these components is about on the order (in practice) is about 50 dB. Great care needs to be taken so that the magnitude of the signal that enters into the ADC is on the order of +/- 1V.

c) Subtractor

The ADC then sends the digitized data to a simple subtractor, and again is clocked at a multiple M of the ring frequency. The goal of the subtractor is to subtract the signals from the opposing electrodes. Note that the CMR of the 180° hybrid is only about -20 dB, while the ADC will enjoy dynamic ranges much greater. The subtraction operation is a simple operation and can be performed quickly. The subtractor then sends the data to memory.

d) Delay

The delay section is a simple section. It is clocked at a multiple M of the ring frequency. The delay section is programmable and simply places data into the memory, and reads it out at N clock periods later. The resolution, therefore, is proportional to how fast the clock works. The maximum delay is proportional to how much memory is implemented into the design.

e) Synchrotron Filter

The synchrotron filter is a simple piece of memory with exactly M elements (this can be easily visualized as a circular buffer of M elements). The filter is clocked at a multiple M of the ring frequency. Data is inserted into the circular buffer, and a simple subtraction of the data from M elements away is performed. This is the identical operation that is performed in the analog case. A great improvement in S/N and CMR is enjoyed in this scheme since two 180° hybrids are not utilized.

f) DAC

The data is finally ready to become analog once again, and is clocked at a multiple M of the ring frequency. This step is fairly clear, and requires no additional discussion.

g) Equalizer

The equalizer is required in this scheme for all the same reasons that it was required in the analog system. The equalization cannot be performed digitally because the damper system is broadband, and requires too much time for the mathematics to be performed. The same method for design of the equalizer would be done for the analog as for the mixed signal system.

h) Amplifier

The amplifier concerns are identical for both systems. No further discussion is necessary

IV) Conclusions

The damper system for the SNS has many possibilities. Two systems are presented in this paper. Each system has its strengths. The analog system is cheaper to build and install, though it has less flexibility, though it will have a longer lifetime. The mixed signal system is more flexible, more expensive, and will have lifetime issues on the order of a few years.

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